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THE COMPARATIVE HISTOLOGY OF FEMORAL BONES.

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It is interesting to notice the diversity of structure present in the femurs of various animals. We have been led to think that bone is bone; that long bones, and especially similar bones wherever they occurr, have the same structure because they are used for the same purposes. This is not true. Microscopical examinations of entire sections of femurs of forty-three different animals show that the structures and their arrangements are not at all the same. They vary in different animals and even in the walls of a bone of any one animal. The anterior wall is unlike the posterior, the outer wall unlike the inner. Nor are the lineal portions of a bone the same. If a long bone, like the femur, is divided into thirds, each third is found to differ from another third. Therefore, a correct knowledge of the histology of bone cannot be obtained from prepared sections of small pieces sawed from the walls of bones. Entire cross sections must be made in each case. Furthermore, a drawing and description of one long bone will not answer for another.

In a general way femurs answer a common purpose, but in specific ways they differ considerably. The various habits of animals, the complex muscular stresses to which their femurs are exposed and the variations in position relative to the bodies which they support demand corresponding structural arrangements peculiar to the animals possessing them. Thus the femurs of swimmers, flyers, scratchers, climbers, crawlers, runners and jumpers differ from each other very decidedly. Bone exhibits a very ready structural response to functional demands.

We are accustomed to one type of bone, viz: the Haversian system type. It is the familiar type described and plated in books. It is human and will not answer as a formula of the general bone structure of animals. In most cases a small piece of a long human bone is described. In some instances entire cross sections of small bones, as the fibula, radius, metatarsal or metacarpal, are given. This type, in its pure form, appears to be peculiar to man, as none of the other femurs examined show it. The completely developed Haversian system evidently belongs to the higher animals.

Entire cross sections of the femurs of the following forty-three animals have been examined as they were received. They were not selected:

LIST OF BONES EXAMINED

AMPHIBIA.

Frog (4 specimens). Pl. A; figs. 1-3; Pl. I; figs. 1, 2.

REPTILIA.

Alligator, Pl. I, fig. 4.
Snapping Turtle, Pl. I; figs. 5, 6.

AVES.

Order Steganopodes
Pelican, Pl. I, fig. 7.

Order Anseres
Mallard Duck, Pl. II; fig. 8.
Wild Goose, Pl. II; fig. 9.

Order Striges
Owl, Pl. II, fig. 10.

Order Accipitres
Eagle, Pl. II; fig. 11.
Hawk, Pl. II; fig. 12.

Order Gallinae
Grouse, Pl. II; fig. 13.
Chicken, Pl. III; fig. 14.
Prairie Chicken, Pl. III; fig. 15.
Domestic Turkey, Pl. III; fig. 16.
Wild Turkey, Pl. III; fig. 17.
Peahen, Pl. III; fig. 18.

Order Picariae
Yellow Hammer, Pl. III; fig. 19.

Order Passeres
Crow, Pl. IV; fig. 20.
Jay, Pl. IV; fig. 21.

MAMMALIA

Marsupials
Opossum, Pl. IV; fig. 22
Placentals

Order Rodentia
Musk Rat, Pl. IV; fig. 24.
Rat, Pl. IV; fig. 25.
Rabbit, Pl. IV; fig. 26.
Squirrel, Pl. IX; fig. 50.
Woodchuck, Pl. V; fig. 27.
Prairie Dog, Pl. V; fig. 28.

Order Carnivora
Skunk, Pl. V; fig. 29.
Raccoon, Pl. V; fig. 30, 32.
Mink, Pl. V; fig. 31.
Weasel, Pl. VI; fig. 33.
Wild Cat, Pl. VI; fig. 34.
Cat, Pl. VI; fig. 35.
Gray Fox, Pl. VI; fig. 36.
Wolf, Pl. VI; fig. 37.
Dog, Pl. VI; fig. 38.

Order Ungulata
Elk, Pl. VII; fig. 39.
Deer, Pl. VII; fig. 40.
Ox, Pl. VIII; fig. 43.
Sheep, Pl. VIII; fig. 44.
Goat, Pl. IX; fig. 51.
Horse, Pl. VIII; fig. 41.
Pig, Pl. VIII; fig. 42.

Order Primates
Monkey, Pl. IX; fig. 52.
Man, Pl. IX; fig. 53.

All sections are taken from the middle of the femurs, ground to proper thinness, mounted in hard balsam and examined with the same objectives, oculars and tube lengths of a Zeiss microscope. Drawings are then made. As some of the femurs are very large and some are very small, all drawings are made from the viewpoint of clearness rather than from actual sizes.

The drawings do not make any effort, therefore, to give the exact number of Haversian systems, laminae, lamellae, etc. The aim has been merely to show the relative positions, arrangements, proportions and developments of these structures. The horizontal line in connection with each femur gives the natural diameter of the bone.

The following general outline is followed in all examinations: (1) antero-posterior diameter of the bone; (2) lateral diameter of the bone; (3) antero-posterior diameter of the medullary canal; (4) latera ldiameter of the medullary canal; (5) medullary canal, full or empty; (6) trabeculae of bone, present or absent; (7) cancellous bone, present or absent; (8) compact bone; (9) hardness or density; (10) character of external and internal circumferential lamellae; (11) arrangement, development and character of the Haversian systems; (12) laminae—concentric or oblique, position of; (13) lacunae, character of; (14) canaliculi, character of; (15) type of structure.

DETAILED DISCUSSION.

Femurs of the Bull Frog.

The femurs of four frogs are examined, the first unusually large, the second of medium size and the third and fourth small. The first femur is 3.5 mm. x 4.5 mm., the second 2.5 mm. x 3 mm., the third and fourth 1 x 1.3 mm.

They show different developments of the same type of bone (Pl. A, Figs. 1, 2, 3; Pl. I, Figs. 1-3).

Femur of the First Frog.

Pl. A, Fig. 1.

Antero-posterior diameter of bone, 3.5 mm.; lateral, 4.5 mm. Antero-posterior diameter of medullary canal, 1 mm.; lateral, 2 mm.

The medullary canal is full. There are no trabeculæ and no cancellous bone. The bone is soft.

Structure. The bone shows three general divisions, viz: (1) external circumferential lamellae; (2) a central ring of radiating canals; (3) internal circumferential lamellae. The external circumferential lamellae, three or four in number, surround the bone. Their lacunae are round and oval, their canaliculi are short and bushy and all are poorly developed. The central ring, situated between the external and internal circumferential lamellae, consists of concentric lamellae, interrupted by forty-two large radiating canals. The lamellae are indistinct, their lacunae are round and oval and the canaliculi communicate with the radiating canals. In some places the canals, with their canaliculi and lacunae, present an appearance similar to stems with fine branches and small leaves.

The canals are just visible to the naked eye, or about 0.25 mm. in diameter. Some of them extend from the internal to the external circumferential lamellae, some about two-thirds of that distance and some are interrupted at various points along their way. The central ring forms about four-fifths of the thickness of the bone, is thicker in the posterior half than in the anterior, and presents a low development.

The internal circumferential lamellae, three or four in number, surround the medullary canal. They are clearer than those of the external lamellae, their lacunae are oval and their canaliculi are short and bushy. In the posterior wall, situated partly in the lamellar and partly in the central ring, is a large vascular canal on its way to the medullary canal. The internal lamellae are poorly developed.

The type of bone is lamellar, poorly developed.

The peculiar features are the radiating canals and the association of poorly developed lamellae and lacunae with them. The bone is an early form of lamellar development.

Femur of the Second Frog.
Pl. A, Fig. 2.

Antero-posterior diameter of bone, 2.5 mm.; lateral, 3 mm.

Antero-posterior diameter of medullary canal, 1.5 mm.; lateral, 1.5 mm.

The medullary canal is full. There are no trabeculæ and no cancellous bone. The bone is soft.

Structure. Around the bone is a very narrow ring of dense lamellae containing a few long, narrow lacunae and long canaliculi.

In the center of the anterior wall is a notch, which extends inward about half of the width of the wall. The notch is a part of the nutrient canal. Beginning a little to the outer side of the posterior mid line and extending around the outer wall, anterior wall, and about one-fourth of the inner wall, the entire thickness of the bone is composed of 16-18 concentric lamellae with oval lacunae and bushy canaliculi. The remaining portion of the bone consists of concentric lamellae in which are cross sections of 36-38 canals arranged radially in twos and threes. The canals are surrounded by clear areas and extending from them in all directions are very fine canaliculi. In the anterior inner wall the canals assume a longitudinal direction. The type is lamellar.

Its peculiar feature is a development intermediate between that shown in the first and third frogs.

Femur of the Third and Fourth Frogs.
Pl. A, Fig. 3; Pl. I, Fig. 1.

Antero-posterior diameter of the bone, 1 mm.; lateral, 1.3 mm. Antero-posterior diameter of the medullary canal, 0.5.; lateral, 0.6 mm.

The medullary canal is full. There are no trabeculæ and no cancellous bone. The bone is soft.

Structure. The section is composed of eight or nine lamellae, concentrically arranged around the medullary canal. There are no divisions into external circumferential lamellae. There are no radiating canals. The lamellae are clear, their lacunae oval, long and narrow and their canaliculi are long and numerous. The type is lamellar.

The peculiar feature is its completeness as compared with preceding figures.

These figures show drawings of femurs taken from the same species of frogs, but of different sizes and weights. The largest, Fig. 1, is lowest in development; the second in size, Fig. 2, is next, and the third, Fig. 3, is last and most complete. They are all of the

lamellar type, though of different developments. In Fig. 1, the radiating canals, with poorly developed intervening lamellae, indicate a low stage of development. In Fig. 2 half of the canals have disappeared and better developed lamellae are formed. In Fig. 3 all of the canals have disappeared and the whole bone consists of concentric lamellae.

Fractured and Repaired Femur of the Frog.
Pl. I, Fig. 2, 3.

One of the femurs (Fig. 2) had been fractured about the middle of the shaft and repaired. The ends of the bone had slipped by each other and new bone had formed around the fragments. In the section, which was taken from the middle of the new bone, two cuts of the femur appear situated eccentrically. The upper fragment, proximal, shows cell growths bursting through the wall of the bone (Pl. I, Fig. 2, A. B.). In the lower fragment, distal, no cell outbursts appear.

Around the two fragments and extending between them is a formation of cancellous bone which is the new bone of repair. The cancellous bone resembles large Haversian systems, although there are no Haversian systems in the femur. This fact suggests a genetic relationship between cancellous bone and Haversian systems, and also indicates that bone repairs are made by cancellous bone. Evidently the lamellar type is the simplest type of bone structure.

Femur of the Alligator.
Pl. I, Fig. 4.

Antero-posterior diameter of the bone, 15 mm.; lateral, 17 mm.
Antero-posterior diameter of medullary canal, 5.5 mm.; lateral, 6 mm.

The medullary canal is full. No trabeculæ. Very little cancellous bone. The bone is hard.

Structure. A thin cross section of this femur held up to the light presents a ringed appearance like that of a cross section of the trunk of a tree.

PLATE A

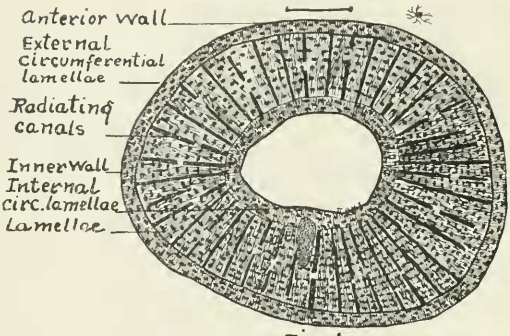


Fig. 1.
Femur of a large Frog showing lamellae interrupted by radiating canals. Low type of structure.

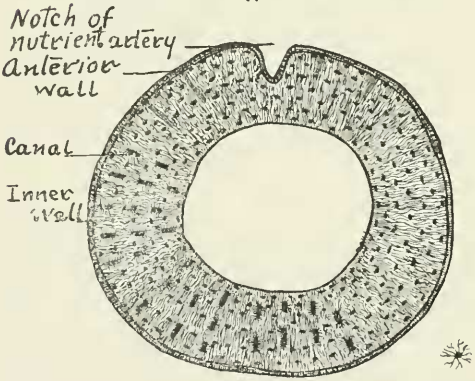


Fig. 2
Femur of Frog, showing a structure intermediate between figs. 1 and 3.

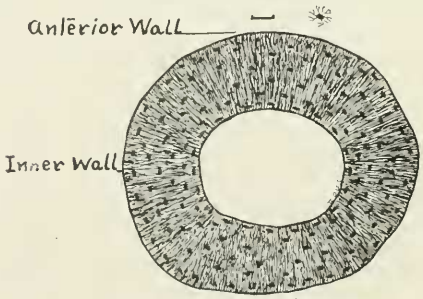


Fig. 3.
Femur of Frog, showing lamellar structure.

Under the microscope the following concentric rings are found, beginning with the circumference:

1. A wide ring composed of irregularly-shaped canals enclosed within a network of canaliculi, radiating from long and oval lacunae, embedded in bone substance. Lamellae do not appear. The ring has the appearance of very incomplete Haversian systems. The lacunae are small or large and their canaliculi are long, branching and bushy.

2. A second narrow, laminar ring composed of two or three lamellae between which are long narrow lacunae, with long, straight canaliculi. The lamellae are well developed.

3. A second ring of incomplete Haversian systems, narrower than the first, but of similar construction.

4. A second narrow lamina, like the first.

5. A third ring of incomplete Haversian systems, like the other two, excepting that it is a little denser.

6. A third lamina, like the two first described.

7. A fourth wide ring of incomplete Haversian systems like the others.

8. A fourth narrow ring of internal circumferential lamellae, three or four in number, interrupted by a little cancellous structure in the inner and outer walls. It may be noticed that the bone has four concentric laminae alternating with four rings of incomplete Haversian systems, which is practically the same structure as found in the femur of the turtle. The bone is hard.

Its peculiar features are the absence of complete Haversian systems, its uniform concentric ringed structure, its laminar development and the presence of incomplete Haversian systems.

Femur of the Snapping Turtle.
Pl. I, Figs. 5, 6.

Antero-posterior diameter, 8 mm.; lateral diameter, 8.5 mm.
Antero-posterior diameter of medullary canal, 1 mm.; lateral diameter, 1 mm.
Medullary canal is full. No trabeculæ.

Structure. The walls of the shaft are very thick, proportionately, and the medullary canal is very small. The femur is nearly

solid. Around the medullary canal is a zone of cancellous bone. Around this is a thick zone of compact bone. The bone is hard. This variation in the relative diameters of the shaft and medullary canal is in marked contrast with the measurements of other femurs. The type of structure is mixed and incomplete. The bone presents quite a complicated arrangement of its structural units, lamellae, laminae and Haversian systems. The following structures appear, beginning with the outer boundary and proceeding toward the medullary canal:

1. A clear peripheral lamella of bone containing only a few irregularly-shaped lacunae, with few canaliculi.

2. A complete concentric lamina of bone composed of four or five lamellae closely united. The lacunae are oval, round or long and narrow and their canaliculi are numerous and bushy.

3. A wide ring of incomplete Haversian systems. These systems are composed of oval or round lacunae arranged around rather large Haversian canals. The canaliculi are radiating in arrangement. The lamellae of the systems are not distinctly marked. The canals are large. The systems present an appearance of incompleteness.

4. A second concentric lamina composed of three or four lamellae of bone with long narrow lacunae and bushy canaliculi.

5. A second wide ring of Haversian systems similar in all respects to the first.

6. A third concentric lamina of three or four lamellae similar to the others described.

7. A third ring of Haversian systems, narrower than the others, otherwise similar.

8. A fourth concentric lamina similar to the others described.

9. A wide zone of cancellous bone surrounding the medullary canal.

Thus the femur has four concentric laminae alternating with three rings of incomplete Haversian systems. The laminae appear to be more completely developed than the systems. All of the laminae and rings of Haversian systems, at one point of the section, bend inward from the external surface to the cancellous central bone.

Femur of the Pelican.

Pl. I, Fig. 7.

Antero-posterior diameter of the bone, 11.5 mm.; lateral, 12 mm. Antero-posterior diameter of the medullary canal, 9.5 mm.; lateral, 10 mm.

The medullary canal is full. There are no trabeculae. The bone is of medium hardness. No cancellous bone.

Structure. External circumferential lamellae, four to ten in number, surround the bone, excepting at the anterior and outer posterior ridges. The lamellae are well developed, their lacunae are long and narrow and their canaliculi are long and branching. At the anterior and posterior ridges the lamellae are interrupted by tendon insertions.

The central ring is composed of Haversian systems in different stages of development. Underneath the external lamellae is a narrow ring of well-developed Haversian systems.

The main portion of the bone is composed of oval and round lacunae, with short, bushy canaliculi, forming a delicate network within the bone substance. There are no lemellae, laminae or Haversian systems. Wide branching canals extend from the medullary canal outward and cross the bone in all directions, forming a coarse network. This portion of the bone resembles reptilian bone (Pl. I, Fig. 4, 5, 6).

The posterior wall consists of rather indistinct whorls of lacunae and their reticular canaliculi bordering on the medullary canal. In some places half of a system forms the boundary line. The outlines of the Haversian systems are more clearly marked in the internal than in the external half of the wall. The lacunae are long and narrow. The internal circumferential lamellae, two or three in number, surround the medullary canal, excepting in the posterior wall. They form an extremely narrow boundary of the medullary canal. The lamellae are only partly developed. The lacunae are oval and the canaliculi are short and bushy.

The section shows a thickening a little to the inner side of the anterior mid line. The external surface has tendon insertions, extending through the external circumferential lamellae. The canals

of this region have a transverse direction. There is another thickening in the outer wall formed of crude Haversian systems and two slight thickenings in the posterior wall formed in a like manner. The type is Haversian system, undeveloped. The peculiar feature of the bone is its low stage of development.

Femur of the Mallard Duck.
Pl. II, Fig. 8.

Antero-posterior diameter of the bone, 4.6 mm.; lateral, 6.3 mm.
Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 5.5 mm.

Medullary canal empty. No trabeculæ and no cancellous bone. The bone differs from that of the wild goose in that it does not show the division into outer and inner rings of Haversian systems and laminæ. It is of medium hardness.

Structure. 1. External circumferential lamellae, four to six in number, with long, narrow lacunae and branching canaliculi.

2. A wide ring of various combinations of irregularly-shaped Haversian systems and short laminae. No plan of arrangement is evident. The systems appear to be a laminar formation doubled or rolled into crude forms. Their lacunae are rather few and their canaliculi are short and bushy. Their lamellae are clearly marked. They run in all directions, as may be seen from their cross sections. The laminae are short (inter-Haversian), and the canals are numerous and frequently intersecting. Their lacunae are long or oval and their canaliculi are bushy.

3. Internal circumferential lamellae, three or four in number, with long lacunae and branching canaliculi. Along the posterior ridge and surface the Haversian systems are more numerous and better developed.

The bone is of the mixed type, but incompletely developed.

Femur of the Wild Goose.
Pl. II, Fig. 9.

Antero-posterior diameter of the bone, 9 mm.; lateral, 8.5 mm.
Antero-posterior diameter of medullary canal, 7 mm.; lateral, 7 mm.

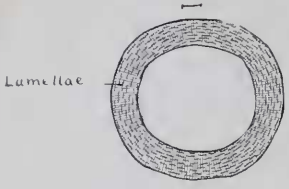


Fig. 1
Femur of a frog
Showing the lamellar
type of structure

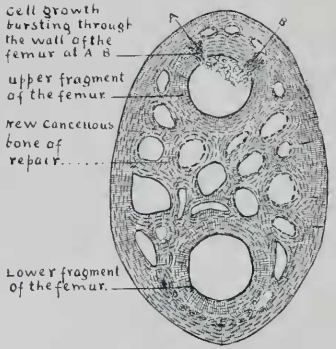


Fig 2.
Fractured and repaired
femur of a frog.

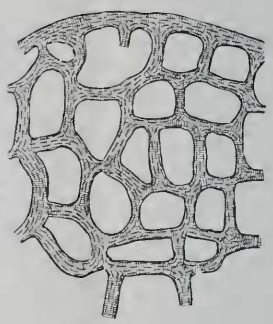


Fig 3.
Cancellous bone

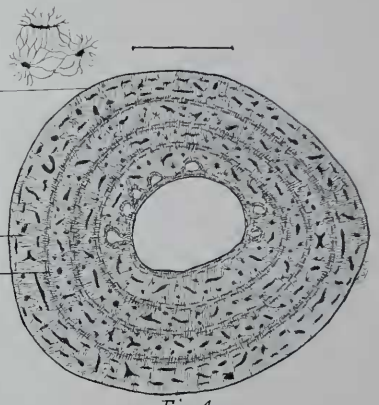
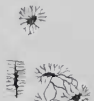


Fig. 4
Femur of an Alligator Showing
Concentric rings of very incomplete
Haversian Systems and laminae



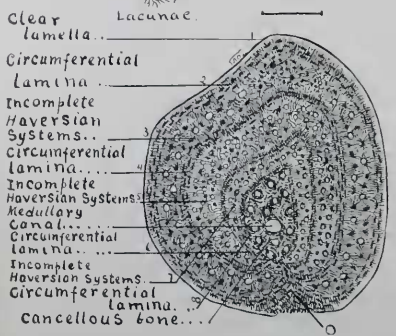


Fig. 5
Femur of a Snapping turtle Showing
alternating Haversian Systems
and Circumferential laminae and
Small medullary canal. medullary
Canal is very Small.

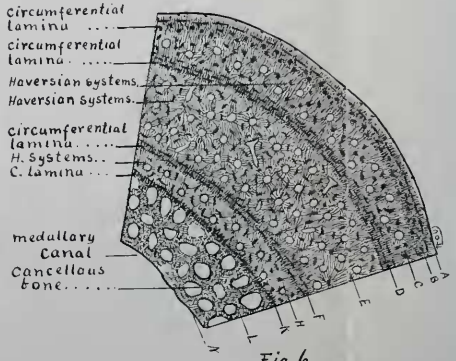


Fig. 6
A portion of fig. 5 enlarged.

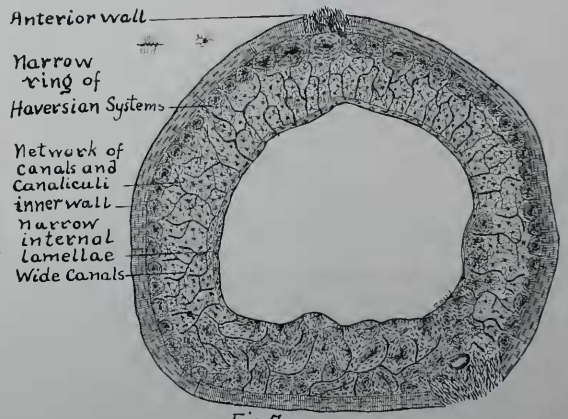


Fig. 7
Femur of a Pelican-showing a low.
stage of development.

Medullary canal is full. No trabeculæ and no cancellous bone. The bone is of medium hardness. The medullary canal is large and the walls of bone are thin.

Structure. The external circumferential lamellae are well developed and vary from four to ten in number. Their lacunae are long and narrow and their canaliculi are rather few in number. At the posterior ridge are found many Haversian systems incompletely developed. Their lacunae are round or oval and their canaliculi are few. The anterior wall of the bone is composed of incomplete Haversian systems occupying the whole thickness of the wall between the external and internal circumferential lamellae. The remainder of the bone, about four-fifths of the whole, shows quite different structures and arrangements in the two walls, outer and inner. The outer wall is composed of irregularly-shaped laminae and undeveloped Haversian systems. The laminae are confined to the inner half of the wall, while the Haversian systems occupy the outer half, situated under the external circumferential lamellae.

The two halves are well marked and distinct from each other. The lacunae of the systems and laminae are oval and their canaliculi are few and short. The Haversian canals of the laminae are irregular and branching. The inner wall of the shaft is composed of an internal band of well-developed laminae and an outer band of rather poorly-developed Haversian systems. The band of Haversian systems is just under the external circumferential lamellae, the band of laminae is just outside of the internal circumferential lamellae. The laminae are better developed than the systems. The peculiar structural feature of the whole wall of the bone is its division into two equal concentric rings, one of Haversian systems and the other of laminae. The internal circumferential lamellae, from three or four to ten or twelve in number, are well developed. On the left side of the bone quite large canals extend from the medullary canal through the laminae to the Haversian canals between the laminae. The type is mixed.

The bone has the following rings beginning with the outside:

1. External circumferential lamellae.
2. Irregular laminae and Haversian systems.

3. Well-developed laminae.

4. Internal circumferential lamellae.

Indistinct arrangements of similar structures are present in the femurs of several other birds.

Femur of the Large Horned Owl.

Pl. II, Fig. 10.

Antero-posterior diameter of the bone, 8 mm.; lateral, 7.5 mm.

Antero-posterior diameter of medullary canal, 6 mm.; lateral, 6 mm.

Medullary canal is full. No trabeculæ and no cancellous bone. The bone is hard, the walls thin.

Structure. 1. The external lamellae vary in number. In some places there are three, in some six, in other places nine. They are narrow, their lacunae are long, numerous and have very fine, long canaliculi. Here and there canals traverse the entire thickness of them all.

2. A ring of small, irregularly-shaped, incomplete Haversian systems. They are best developed along the posterior ridge. In the anterior wall they are few and confined to the region which is just below the surface. Between the posterior and anterior middle lines they are rather indistinct, on account of their shape, arrangement and incomplete formation. The canals are short or long, angular and branching. They are very prominent and reunite with each other frequently. Along some of them are lamellae, along others incomplete Haversian systems. The entire ring impresses one as a transitional blending of lamellae into Haversian systems. The lacunae are oval, numerous and have bushy canaliculi.

3. The internal circumferential lamellae differ from others examined. They form a thick, heavy ring around the medullary canal. There are thirteen to twenty of them, which, on the outer wall of the bone, merge into six laminae. The whole ring of the internal lamellae forms about one-third of the thickness of the wall of the bone. It is traversed by many canals extending from the medullary canal into the canals of the Haversian systems. Their lacunae are long and numerous and their canaliculi are bushy. The bone is of

the Haversian system type undeveloped. The peculiar feature of the bone is the thick, well-developed internal circumferential lamellae which merge into laminae.

Femur of the Eagle.

Pl. II, Fig. 11.

Antero-posterior diameter of the bone, 13 mm.; lateral, 14 mm. Antero-posterior diameter of the medullary canal, 11 mm., lateral, 11.5 mm.

Medullary canal is empty. Trabeculæ are present in the lower third. No cancellous bone. The bone is of medium hardness.

Structure. The external circumferential lamellae, six to ten in number, surround the bone, excepting at two posterior ridges, where they are interrupted by tendon attachments. They are fully developed. Their lacunae are long, narrow and concentrically arranged and their canaliculi are rather short and branching.

The central ring of bone is composed of six to twelve concentric laminae, interrupted here and there by poorly-developed Haversian systems. The canals which separate the laminae are relatively wide and, on account of their frequent communications with neighboring canals, they present the appearance of a coarse network.

The laminae are mostly short and consist of four to six or seven lamellae. Their lacunae are oval or round and their canaliculi are short and bushy. They indicate a low stage of development. A few poorly-developed Haversian systems are scattered among the laminae and in some instances appear to be circular dilatations of the concentric canals.

Internal circumferential lamellae, six to twelve in number, surround the medullary canal. They are fully developed and are frequently crossed by canals extending inward from the medullary canal. Their lacunae are long and narrow and their canaliculi are long and branching.

On the posterior surface are two ridges, one central and one on the posterior inner lateral border. The bone at these points consists of poorly-developed Haversian systems, separated by frequent wide

canals, which pass to an apex at the outer surface of the ridges. The external circumferential lamellae are absent at these points and tendon insertions, interspersed by many canals, occupy the ridges.

The peculiar features of the bone are its undeveloped condition and its resemblance to the femurs of the peahen and turkey. The eagle's medullary canal is empty, like that of the peahen, but its laminar structure is more like that of the turkey. The type is incomplete laminar.

Femur of the Hawk.
Pl. II, Fig. 12.

Antero-posterior diameter of bone, 4 mm.; lateral, 4.3 mm.
Antero-posterior diameter of medullary canal, 3 mm.; lateral, 3.3 mm.
The medullary canal is empty. The bone is hard.

Structure. The section is surrounded by four to six external circumferential lamellae, fairly well developed. Their lacunae are more frequently oval than long. This fact indicates a less complete development. The canaliculi are bushy.

In the inner lateral posterior wall is a ridge to which are attached muscle tendons penetrating the external lamellae. Underneath the external circumferential lamellae is a thick ring of incomplete Haversian systems with oval lacunae and short, bushy canaliculi. The ring is crossed at all angles by wide, irregular canals, which are mostly confined to the ring. The Haversian systems are most prominent and best developed near the ridge of the lateral posterior region. This central Haversian system ring blends with the external circumferential lamellae.

The medullary canal is enclosed by six or eight well-developed internal circumferential lamellae with long lacunae and canaliculi. It is distinct from the central ring. No cancellous bone.

The peculiar feature of the bone is its low development. The type is incomplete Haversian system.

Femur of a Grouse.

Pl. II, Fig. 13.

Antero-posterior diameter of the bone, 5 mm.; lateral, 5.5 mm. Antero-posterior diameter of the medullary canal, 4 mm.; lateral, 5 mm.

The medullary canal is empty. Trabeculæ are present in the lower third. The bone is soft. No cancellous bone.

Structure. There are no distinct external circumferential lamellae. The bone, with the exception of a narrow ring of internal circumferential lamellae, is composed of short concentric laminae, separated by wide canals. Each lamina consists of two to four lamellae, with long, narrow or oval lacunae and long, branching or bushy canaliculi. The canals freely communicate with each other across the laminae. In the anterior wall (middle portion) is a slight prominence or ridge, consisting of three or four poorly-developed Haversian systems, situated close to the external surface and several whorls of lamellae arranged around short canals running in different directions. In the posterior wall are two ridges separated by a concave surface of bone. A single, poorly-developed Haversian system is found at the apex of each ridge, around which are collections of oval lacunae, with short, bushy canaliculi. Close to the internal circumferential lamellae are a few Haversian systems of a crude type.

Internal circumferential lamellae, three or four in number, surround the medullary canal. Their lacunae are long and narrow. The type of bone is the laminar.

The peculiar feature is the absence of complete Haversian systems. The bone resembles that of a turkey.

Femur of the Domestic Chicken.

Pl. III, Fig. 14.

Antero-posterior diameter of the bone, 9 mm.; lateral, 9 mm. Antero-posterior diameter of the medullary canal, 7 mm.; lateral, 7 mm.

The bone is practically round. The medullary canal is full. No trabeculæ and no cancellous bone. It is of medium hardness.

Structure. 1. Well-marked external circumferential lamellae, three to five in number, with long, narrow lacunae and branching canaliculi. They are quite distinct from the remainder of the bone.

2. A wide ring of irregularly-shaped, incompletely-developed Haversian systems. Some of the systems are circular in cross section, but most of them exhibit no definite shape. They run in various directions, are better developed on the outer side than on the inner side and tend to centralize at the posterior ridge and anterior surface. At the posterior ridge they occupy the entire thickness of the wall of the bone as far as the internal circumferential lamellae. At the ridge surface canals and bone lamellae take a direction at right angles to the long axis of the shaft. Along the anterior surface the systems are better developed and extend a short distance on both sides of the middle line. Interspersed between the systems are short lamellae. The lacunae of the systems are oval and the canaliculi are short and bushy. The Haversian canals are prominent in some places where they form a network, while in other places they form a parallel system.

3. Internal circumferential lamellae, four or five in number, completely surrounding the medullary canal. Their lacunae are long and narrow and their canaliculi are bushy.

Both external and internal lamellae are well-developed and distinct from the Haversian ring. The bone is of the Haversian system type undeveloped.

Femur of the Prairie Chicken.
Pl. III, Fig. 15.

Antero-posterior diameter of the bone, 5 mm.; lateral, 6 mm.

Antero-posterior diameter of the medullary canal, 4 mm.; lateral, 4.5 mm.

The medullary canal is empty. Trabeculæ are present. The bone is soft. No cancellous bone.

Structure. There are no distinct external circumferential lamellae. The bone is composed of crude lamellae, crossed at all angles by short canals, some of which extend inward from the external surface. In the posterior and outer walls they unite and form a coarse network, while in the anterior and inner walls they

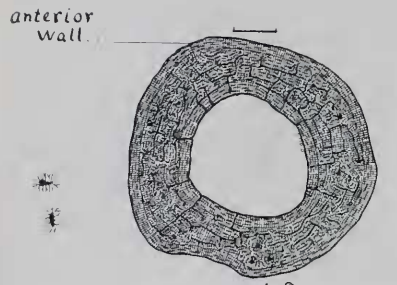


Fig. 8

Femur of a mallard Duck showing External, internal lamellae and various Combinations of irregular laminae and Haversian systems.

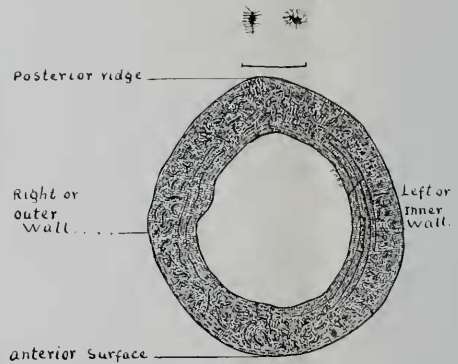


Fig. 9

Femur of wild goose showing incomplete Haversian Systems. laminae and lamellae

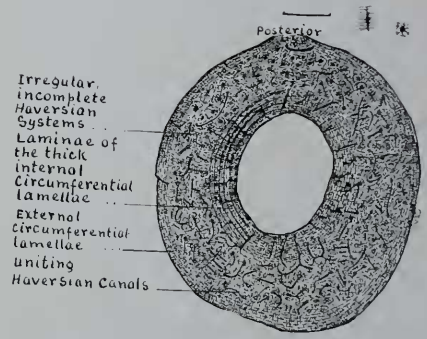


Fig. 10

Section of the femur of the large horned owl showing a thin band of external circumferential lamellae incomplete Haversian Systems and thick band of internal circumferential Lamellae and prominent uniting Haversian Canals.

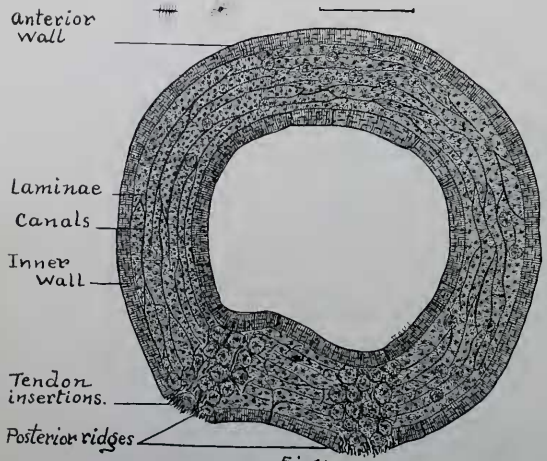


Fig. 11

Femur of an Eagle.

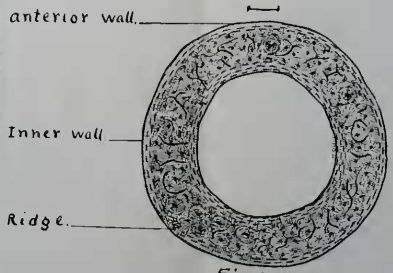


Fig. 12

Femur of a Hawk
Showing well developed external and internal Lamellae and andeveloped Central Haversian Systems

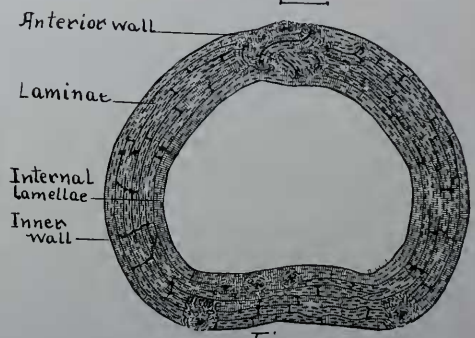


Fig. 13

Femur of Grouse (Blue), Showing Laminar Structure.

do not. The lamellae are not distinct, but are blended together. Their lacunae are oval or narrow and their canaliculi are bushy or long and branching.

A very few crude Haversian systems are found interrupting the lamellae of the anterior and inner walls. They have only three or four lacunae around a minute canal. Their canaliculi are few. In the posterior wall are two ridges separated by a concave surface of bone. Two or three undeveloped Haversian systems are found in each ridge.

The internal circumferential lamellae, four to six in number, surround the medullary canal. They are well developed. Their lacunae are long and narrow and their canaliculi are long and branching. The type of bone is lamellar.

The peculiar features are the general absence of Haversian systems and the crude lamellar formation. The bone is not as far advanced as that of the grouse (Blue).

Femurs of the Domestic and Wild Turkey.
Pl. III, Figs. 16, 17.

Domestic turkey.	Antero-posterior diameter, 15 mm.; lateral, 17.5 mm.
	Antero-posterior diameter of medullary canal, 10.5 mm.; lateral, 13 mm.
Wild turkey.	Antero-posterior diameter, 9 mm.; lateral, 11 mm.
	Antero-posterior diameter of medullary canal, 7 mm.; lateral, 8 mm.

Since the two bones resemble each other closely, one description will answer for both. The medullary canals are full. No trabeculæ; no cancellous bone. The type of structure is laminar. The bones are soft. The medullary canals are relatively large and the walls of the bones are thin.

Structure. Around the outside are four or five external circumferential lamellae, between which are long, narrow lacunae, with many canaliculi. Along the posterior ridges of the two femurs are small areas of incomplete, irregularly-shaped Haversian systems which occupy nearly the entire thickness of the posterior walls of

the bones. They extend nearly to the outer surfaces, where they seem to be projected in a network of bone extensions, which pass to the surfaces of the posterior ridges, where they blend with the tendon attachments. In the anterior walls are small areas of the same irregular Haversian systems. The systems do not reach either surface. In both of these regions the systems do not appear to run parallel with the outer and inner surfaces of the bones, but extend in different directions. Since their cross sections are circular, elliptical, angular and very irregular in shape, no one direction could be followed by all. The Haversian canals are large, the lacunae are oval and their canaliculi are numerous and bushy.

Between the posterior ridges and middle anterior surfaces, and constituting eight-tenths of the whole section of the bones, are concentric laminae, fifteen to eighteen or twenty in number, separated by prominent canals and crossed at frequent intervals by smaller canals extending from both surfaces of the bones. The laminae are composed of three or four lamellae, between which are oval lacunae, with short, bushy canaliculi. Here and there a lamina is interrupted by a Haversian system.

Around the medullary canal the internal circumferential lamellae are not distinct from the adjoining laminae. The peculiar feature of the turkey femurs is the laminar formation.

It may be noticed that the Haversian systems present in the section are found in the posterior walls and ridges and in the anterior walls, where muscular stress is greatest.

Femur of the Peahen.
Pl. III, Fig. 18.

Antero-posterior diameter of the bone, 10 mm.; lateral, 11 mm.

Antero-posterior diameter of medullary canal, 8 mm.; lateral, 10 mm. Bone is thin; medullary canal is large, empty; has a network of trabeculæ which extends from one wall in a downward direction to the opposite wall. They are most numerous near the extremities of the bone. No cancellous bone. The bone is extremely hard.

Structure. The usual three divisions of the bone into external circumferential lamellae, middle ring of Haversian systems and in-

ternal circumferential lamellae do not appear. The bone consists of a network of canals separating short, concentric laminae. The canals intersect at all angles. They are wide. The laminae are composed of four or five lamellae with oval lacunae and relatively few rather short, bushy canaliculi. In the vicinity of the posterior ridge a few incomplete Haversian systems are found. In other parts of the section, here and there, a system appears without any apparent signification. The bone is peculiar in the absence of Haversian systems. The bone trabeculae are composed of three or four lamellae with long, narrow lacunae and branching canaliculi. A few systems are present. The bone is of the laminar type, but does not show a development equal to that of the turkey. However, it belongs to the same structural type and can be recognized as such with no difficulty.

Femur of a Yellow Hammer.
Pl. III, Fig. 19.

Antero-posterior diameter of the bone, 2.5 mm.; lateral, 3 mm.
Antero-posterior and lateral diameters of the medullary canal, 0.5 mm.
The medullary canal is full and situated close to the posterior wall. The bone is soft.

The femur consists of a wall of compact bone, composed of three or four external circumferential lamellae and about the same number of internal circumferential lamellae, between which are a few irregularly-developed Haversian systems. Large canals extend transversely across the walls of the bone communicating with the meshes of the central bone structure.

The central portion of the bone usually occupied by the medullary canal is composed of a fine cancellous bone formation, with the exception of a fine medullary canal about the size of a fine sewing needle, situated close to the posterior wall. The femur is therefore nearly solid bone. The cancellous center is composed of fine lamellae forming a meshwork extended from the internal circumferential lamellae. The meshes are filled with granular material, insoluble in ether or chloroform. It is difficult to grind out this

material and leave uninjured the meshwork. The lacunae are small, round or oval and their canaliculi are short, bushy and infrequent. Round and oval lacunae appear to be antecedent forms of long, narrow lacunae. In undeveloped Haversian systems the lacunae are round or oval, while in the complete systems they are long and narrow. It is possible that the pressure of development accounts for the variation in shape—the medullary canal is full and extremely small. Its position is unlike that of other canals.

The peculiar features of this femur is the central bone formation and small eccentric medullary canal. Although the yellow hammer is a good flyer, its femur is practically a solid bone. The type is lamellar-cancellous.

Femur of the Crow.
Pl. IV, Fig. 20.

Antero-posterior diameter of the bone, 4 mm.; lateral, 3 mm.
Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 2 mm.

The medullary canal is full. No trabeculæ and no cancellous bone. The bone is soft.

Structure. 1. External circumferential lamellae, six or eight in number, form a wide lamina around the bone. The lamellae are not clearly defined, the lacunae are oval, with bushy, connecting canaliculi. A little to the outer side of the anterior mid-line, the lamina dips down and forms a semi-circular depression about ¼ mm. in diameter.

2. A central wide ring of transverse canals, enclosed by incomplete Haversian systems and irregular lamellae. Their lacunae and canaliculi are the same as above described. There is very little difference in the structure of the various parts of the bone. Possibly the Haversian systems are a little better developed in the posterior wall.

3. Internal circumferential lamellae, two or three in number, form a narrow ring around the medullary canal. Their lacunae are narrow and long and their canaliculi are long and branching.

The bone is of the mixed type. The peculiar features are the external lamina, uniform central ring and semi-circular depression.

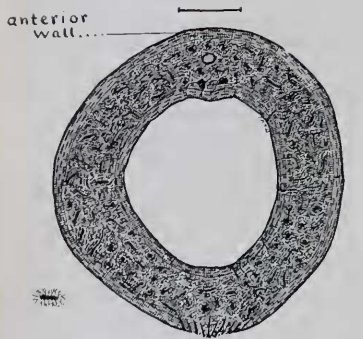


Fig. 14

Femur of domestic chicken showing external, internal lamellae and irregular Haversian Systems.

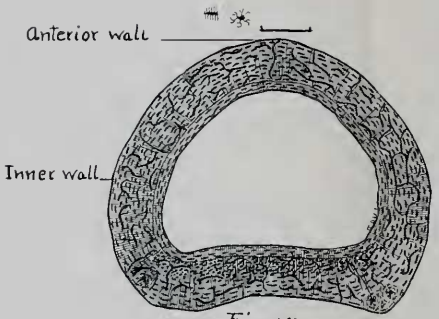


Fig. 15

Femur of a Prairie Chicken showing lamellar type.

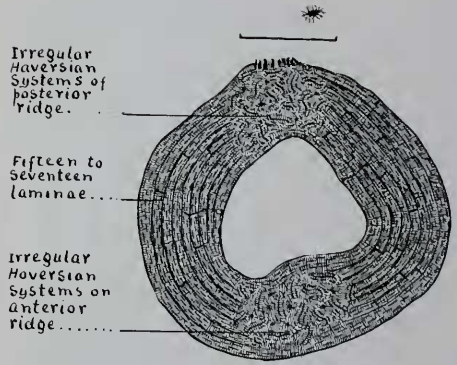


Fig. 16

Femur of domestic turkey showing laminae and irregular Haversian Systems on anterior and posterior ridges.

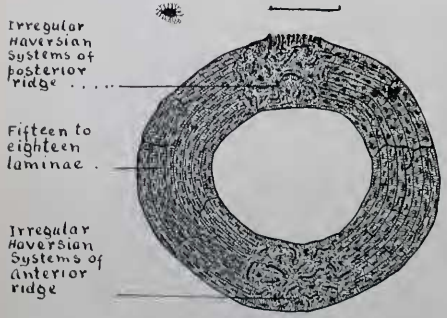


Fig. 17

Section of the femur of a wild turkey showing laminae and irregular Haversian Systems on anterior and posterior ridges.

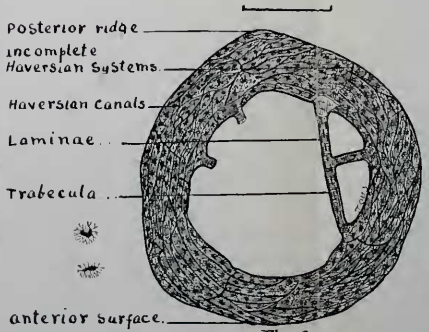


Fig. 18

Femur of a peahen showing a network of Haversian Canals, Short laminae, few Haversian Systems and trabeculae of bone

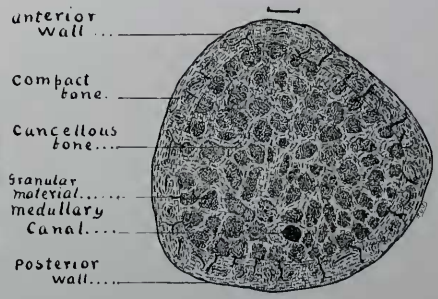


Fig. 19

Femur of yellow hammer. Extremely small medullary canal near posterior wall. The femur is nearly all bone from one wall to another. The meshes of the central bone are filled with granular material

Femur of a Blue Jay.
Pl. IV, Fig. 21.

Antero-posterior diameter of bone, 2.5 mm.; lateral, 2.5 mm.
Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 1.5 mm.

The bone is nearly round. The medullary canal is full. The bone is hard.

Structure. The anterior and outer walls are composed of four or five incompletely-formed laminae, frequently uniting. The laminae consist of three or four lamellae. The inner and posterior walls are composed of lamellae interrupted by a few incompletely-developed Haversian systems. The lacunae are oval. The canaliculi are few and short.

The type of bone is lamellar. The peculiar feature of the bone is its close conformity to the lamellar type and absence of Haversian systems.

Femur of the Opossum.
Pl. IV, Fig. 23.

Antero-posterior diameter of the bone, 7 mm.; lateral, 8.5 mm.
Antero-posterior diameter of the medullary canal, 3.5 mm.; lateral, 5 mm.

Medullary canal is full. No trabeculæ and no cancellous bone. The bone is soft.

Structure. The bone presents a rudimentary appearance. It is composed of two wide external lamellar bands of incomplete formation separated by a very narrow band of imperfectly-developed Haversian systems, the whole occupying two-thirds of the posterior, outer and anterior walls. The lamellar bands simply give the general appearance of lamellae, but are really composed of large oval lacunae, with extensive, bushy canaliculi forming an intricate network. At short intervals short transverse canals appear, with many radiating canaliculi. Just internal to this lamellar band is a narrow crescent of very incomplete Haversian systems occupying the anterior, outer and posterior walls. The systems are merely canals, from which radiate numerous straight canaliculi, with a few oval lacunae around their apparent circular boundaries. Around the

medullary canal of the anterior, outer and posterior walls internal circumferential lamellae are well developed, reaching their greatest thickness in the outer wall. Their lacunae are long and narrow and their canaliculi are long, straight and branching.

The inner wall of the bone is extended in the form of a heavy ridge. It is composed of heavy, oblique canals, from which are sent off dense networks of large canaliculi. This peculiar arrangement forms the external half of the ridge. The internal half consists of incomplete Haversian systems, arranged in oblique rows, converging to a central point in the middle of the ridge. The systems are similar to those described above. No internal circumferential lamellae are found in this region. The bone is very poorly developed and belongs to a type of structure characterized by incomplete development.

The peculiar features are the undeveloped lamellar and Haversian systems and the heavy oblique canals. The only complete structure is the partial internal circumferential ring of lamellae.

Femur of the Musk Rat.
Pl. IV, Fig. 24.

Antero-posterior diameter of the bone, 5 mm.; lateral, 6.5 mm.
Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 3 mm.

Medullary canal has no contents. From the medullary surface of the inner wall project a few fine trabeculae. No cancellous bone. The bone is soft.

Structure. The bone is peculiar in many respects. The inner wall of the bone is extended in the form of a ridge, which is composed of a network of laminae and canals running transversely from above downwards and occupying the outer four-fifths of the ridge. Each lamina consists of two or three lamellae, with long or oval lacunae and long branching or bushy canaliculi. The inner one-fifth of the ridge wall consists of a network of laminae running from the medullary canal to the outer network. Within its meshes are found canals from which radiate many long, branching canaliculi. The remainder of the bone (anterior, outer and posterior walls) is composed of a very irregular, wide internal ring of lamellae sur-

rounding the medullary canal and having an outer wavy border, in some places distinct and in other places fused with an external network of laminae. Very many canals cross the lamellae on their way from the medullary canal to the interior of the wall. Within the lamellar ring are several round or elliptical bodies composed of 6-8 lamellae running lengthwise of the cross section. These bodies are such as would result from a transverse section of solid pillars. In the outer wall of the bone, lamellae form the entire thickness. Here and there occurs a very incomplete Haversian system, consisting of a central canal and radiating canaliculi.

The bone is of the lamellar type modified. Its peculiar features are the networks of laminae and canals, the irregular lamellae, the circular or elliptical solid bodies, and the numerous canals.

Femur of a Rat.

Pl. IV, Fig. 25.

Antero-posterior diameter of the bone, 2.5 mm.; lateral, 3.5 mm.

Antero-posterior diameter of the medullary canal, 1.5 mm.; lateral, 2.5 mm.

The medullary canal is full. No trabeculæ and no cancellous bone are present. The bone is soft.

The bone has a prominent ridge in the outer wall and is somewhat egg-shape in transection.

Structure. It is composed of two concentric rings of about equal width surrounding the medullary canal. The external ring consists of lamellae, varying in number from thirteen to fifteen in the outer ridge to six or eight in the anterior and posterior walls and ten to twelve in the inner wall. The lacunae are long and narrow and their canaliculi are long and branching. Here and there cross canals appear. The internal ring consists of a network of canals, enclosing few incomplete Haversian systems, short lamellae or laminae and, in some places, fine network of canaliculi. The lacunae are oval and round and the canaliculi are bushy. The lamellae are complete. The internal circumferential lamellae are so blended with the other structures of the internal ring that they are poorly defined.

The bone is lamellar in type. Its peculiar features are the two rings, one external complete lamellae and the other internal incomplete Haversian systems and canalicular network.

Femur of the Rabbit.

Pl. IV, Fig. 26.

Antero-posterior diameter of the bone, 5.5 mm.; lateral, 7.5 mm.
Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 5 mm.

The medullary canal is full. No trabeculæ and no cancellous bone are present. The bone is soft.

Structure. 1. Around the bone is a ring of lamellae of varying thicknesses. As a whole it is narrow, and, in the posterior wall, merges into oblique laminae which join the internal circumferential lamellae. The lacunae are long and narrow and the canaliculi are long and branching.

2. There is a wide central ring of incomplete Haversian systems and short, irregular laminae occupying the anterior and inner walls. In the posterior wall this ring is interrupted by oblique, well-developed Haversian systems and laminae extending from the internal to the external circumferential lamellae. In the outer wall there are wide, oblique canals separating irregular laminae extending from the internal to the external lamellae and interdigitating with extensions from the periosteum. These two oblique arrangements enclose a small crescent of irregular systems and lamellae. The lacunae are oval or long and the canaliculi are bushy.

3. Internal circumferential lamellae of varying thickness and well-developed surround the medullary canal. In the inner and posterior walls it merges into oblique, wide laminae, separated by an oblique row of complete Haversian systems. To the outer side of this row of systems are three or four wide, oblique laminae which appear to be extensions of the internal lamellae.

The bone is of the mixed type. Its peculiar features are the oblique Haversian systems and laminae.

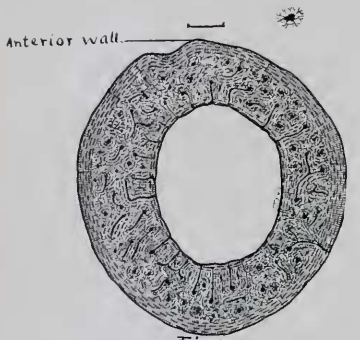


Fig. 20

Femur of Crow showing lamina, depression and irregular systems.

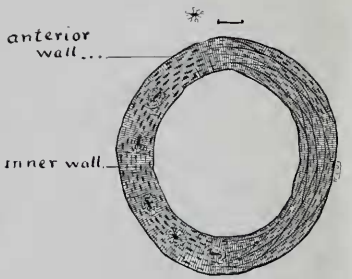


Fig. 21

Right femur of a Blue Jay showing laminae lamellae and a very few Haversian Systems.

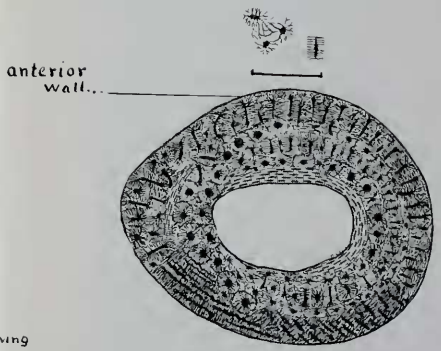


Fig. 23

Femur of the opossum showing incomplete lamellae, Haversian Systems and heavy oblique canals.

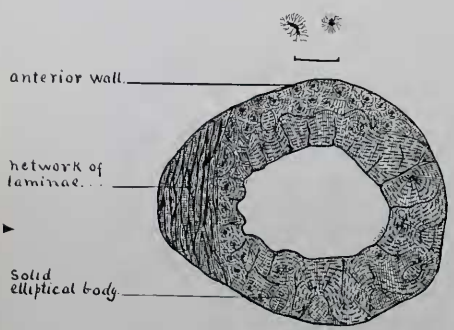


Fig. 24

Femur of a musk Rat showing a very peculiar arrangement of laminae lamellae and incomplete Haversian Systems.

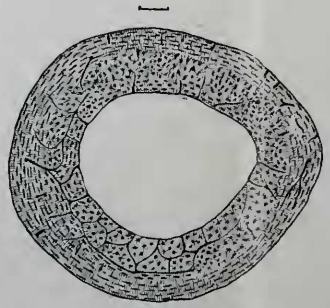


Fig. 25

Femur of a rat showing wide rings of external circumferential Lamellae and internal incomplete Haversian Systems and lamellae with a network of canals.

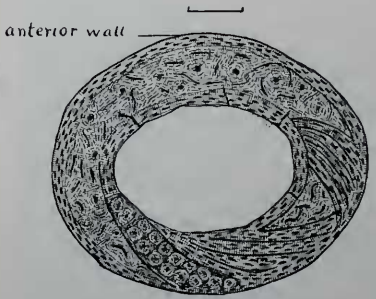


Fig. 26

Femur of a rabbit showing lamellae, Haversian Systems and oblique laminae.

Femur of the Woodchuck or Ground Hog.
Pl. V, Fig. 27.

Antero-posterior diameter of the bone, 6 mm.; lateral, 7 mm.
Antero-posterior diameter of the medullary canal, 4 mm.; lateral, 4.5 mm.

The medullary canal is full. It has no trabeculæ nor cancellous bone. The bone is soft.

Structure. 1. Two well-developed external laminae, distinctly separated, form the circumference of the bone. In the posterior portion of the outer wall they fuse and form a single lamina. Each lamina is composed of five or six lamellae with large round or oval lacunae and bushy canaliculi. In the center of each lamina, and concentric with their boundaries, is an incomplete ring of crude Haversian systems. The two laminae are separated by a wide canal. The external lamina is thickest in the inner wall.

2. A central ring of rugged, irregularly-shaped Haversian systems between which are short lamellae with no apparent regularity. In some places the lamellae are merged into laminae. The lacunae of the Haversian systems are long, their canaliculi are thickly set, long and branching and their lamellae are distinct.

3. Two well-developed internal laminae distinctly separated from each other. Each lamina is composed of five or six lamellae with large round or oval lacunae and long canaliculi. At one point (A) of the medullary surface of the inner wall are seen outgrowths from the medullary canal breaking through the laminae.

The bone is of the complete mixed type. Its peculiar features are the strongly-developed external and internal laminae, the irregular character of the Haversian systems and the medullary outgrowths.

Femur of the Prairie Dog.
Pl. V, Fig. 28.

Antero-posterior diameter of the bone, 4.5 mm.; lateral, 5 mm.
Antero-posterior diameter of medullary canal, 2.5 mm.; lateral, 3 mm.

The medullary canal is empty. No trabeculæ and no cancellous bone. The bone is soft.

Structure. 1. External circumferential lamellae, eight to fifteen in number, form an irregularly wide ring, which reaches its greatest width in the inner wall. The lacunae are long and narrow and the canaliculi are long.

2. A narrow central ring of incomplete Haversian systems. Their lamellae are indistinct, their lacunae are oval and their canaliculi are bushy.

3. A very wide ring of internal circumferential lamellae, six to twenty-five in number. The ring is widest in the anterior wall. Their lacunae are long and narrow and their canaliculi are long. Numerous canals pass from the medullary canal across the lamellae into the interior of the bone.

The bone is of the lamellar type, with a few Haversian systems of an incomplete formation.

Femur of the Skunk.

Pl. V, Fig. 29.

Antero-posterior diameter of the bone, 5 mm.; lateral, 5 mm.
Antero-posterior diameter of medullary canal, 3.5 mm.; lateral, 4 mm.

Medullary canal is full. No trabeculæ and no cancellous bone. The bone is of medium hardness.

Structure. 1. A thick ring of external circumferential lamellae, fourteen to seventeen in number, in the middle of which is a concentric row of very incomplete Haversian systems. The lamellar ring is interrupted in the posterior wall by Haversian systems. The lacunae of the lamellae are long and branching or short and bushy. The concentric row of Haversian systems within the external lamellae consists of Haversian canals, a short distance apart, around which are one or two indistinct lamellar with oval lacunae and short, bushy canaliculi.

2. A narrow, somewhat irregular ring of poorly-developed Haversian systems, the canals of which frequently unite. This ring widens at the posterior wall, where it occupies the entire thickness of it, excepting the internal circumferential lamellae. The lacunae are oval and few and their canaliculi are short and bushy.

3. Internal circumferential lamellae, thin in the posterior wall, six to eight in number and very thick elsewhere, eighteen in number. In the outer wall this ring has a concentric central row of incomplete Haversian systems. The lacunae are long and narrow and their canaliculi are long and branching. Many canals pass through this lamellar ring on their way from the medullary canal to other canals in the interior of the wall.

The bone is of the mixed type. Its peculiar features are the wide rings of lamellae with central rows of Haversian systems and incomplete development.

Femur of the Raccoon.

Pl. V, Fig. 30.

Antero-posterior diameter of bone, 9 mm.; lateral, 10 mm.

Antero-posterior diameter of medullary canal, 6.5 mm.; lateral, 7 mm.

Medullary canal is full. No trabeculæ. No cancellous bone. The bone is of medium density or hardness.

Structure. 1. External circumferential lamellae, fourteen to fifty in number, according to locality. In the anterior wall the lamellar ring is thin, being composed only of a few lamellae, while, in the posterior and inner walls, it reaches its greatest thickness, forming in those regions two-thirds of the entire thickness of the bone. Numerous canals appear at short intervals within the ring. Within the wide lamellar ring of the inner wall are found many rather incomplete Haversian systems. The lacunae of the lamellae are long and narrow and the canaliculi are long.

2. An irregularly-shaped ring of Haversian systems well developed. In the middle of the posterior wall it is thin, one-third or one-fourth of the thickness of the wall. It gradually increases in thickness in the outer wall until it reaches about the middle, where it forms two-thirds of the width of the wall. From this point it continues to increase to the middle of the anterior wall, where it forms four-fifths of the bone. The systems are strongly developed. They have three to five well-marked lamellae, their lacunae are long and narrow and their canaliculi are long and branching. Between

the systems are short lamellae. The Haversian canals frequently unite. In the middle of the lamellar ring of the outer wall are thirty to thirty-five very distinct Haversian systems separated by lamellae. These systems seem to form a group by themselves without any especial signification.

3. A ring of internal circumferential lamellae and laminae of varying thicknesses. In the anterior wall only a few lamellae appear. The Haversian systems almost border the medullary canal. In the outer wall extending around the posterior region are short, oblique laminae, forming in some places nearly one-half of the thickness of the bone. In the inner wall two or three laminae form the medullary boundary. The lacunae are long and narrow and the canaliculi are long and branching.

The femur is of the mixed type. The peculiar features of the bone are the wide external lamellae, the irregular arrangement of the Haversian systems and the oblique internal laminae (compare os penis, Fig. 32).

Os Penis of the Raccoon.

Pl. V, Fig. 32.

The os penis is introduced here because it resembles the Haversian system type of femurs.

The antero-posterior diameter of the bone is 4 mm.; lateral, 4 mm.

The antero-posterior diameter of the central canal is 0.8 mm.; lateral, 0.8 mm. The canal is very irregular in shape. The bone is of medium hardness.

Structure. 1. External circumferential lamellae, seven to twelve in number, and rather incompletely developed. They are not equally distinct in all parts. In some places they are fairly well developed, while in others they are indistinct and interrupted by small, incompletely-formed Haversian systems. The lacunae are large, few in number, oval in shape and have branching canaliculi.

2. A wide ring of large and small Haversian systems. The large systems occupy the inner portion of the ring, the small ones the outer portion. They are all fairly well developed. Their Haversian canals frequently communicate with each other, their cross sections

are circular, their lacunae are few, long and narrow, their canaliculi are long and branching and their lamellae are not clearly defined. Here and there short inter-Haversian lamellae appear.

3. Internal circumferential lamellae, six or eight in number, which form a very irregular boundary of the medullary canal by the formation of large cancellous spaces. The lamellae seem to be folded into cancellous structures. The lacunae are long and their canaliculi are very numerous and branching.

The peculiar feature of this bone is its close resemblance to the structure of some femurs. This resemblance is unexpected, since the requirements of the two bones are apparently quite different. The inference is that the structure of a bone is governed more by the individual, formative character present in an animal than by the function; that is, when a bone is formed the forces at work in the arrangement of its structural units are the same in all parts and the same type of bone is constructed in the penis as elsewhere.

Femur of the Mink.

Pl. V, Fig. 31.

Antero-posterior diameter of the bone, 3.5 mm.; lateral, 4.5 mm.

Antero-posterior diameter of the medullary canal, 1.5 mm.; lateral, 2 mm.

The medullary canal is full. No trabeculæ and no cancellous bone.

Structure. The usual arrangement of lamellae and Haversian systems is not present in this bone. A portion of the anterior wall consists of 50-60 lamellae, forming the entire thickness of the bone. These lamellae then diminish in number to 25-20-12, and form an irregular complete ring around the medullary canal. Numerous canals pass across this ring, incompletely or completely, on their way from the medullary canal to small canals of the interior. The lacunae are long and narrow and their canaliculi are long and branching.

The Haversian systems are absent at the widest lamellar point. They then begin to appear, in single file, gradually increase in thickness to the posterior wall and diminish again as they approach the anterior wall. In this manner they form an irregular crescent en-

closed within outer narrow lamellae and wide inner lamellae. The crescent nearly encircles the bone. The Haversian systems are fairly well developed, their lamellae rather indistinct, their lacunae oval and their canaliculi relatively few. Their canals frequently unite. In some places bands of lamellae cross the crescent extending from the outer to the inner lamellae. Numerous canals traverse the crescent. The internal circumferential lamellae form a wide, irregular ring, fusing with the external lamellae in the anterior wall. Many canals cross them. The lacunae are long and narrow and their canaliculi are long and branching.

The bone is of the mixed type. The peculiar features of the bone are the wide internal lamellar ring, with its many canals, the narrow external lamellar ring and the long crescent of Haversian systems.

Femur of a Weasel.
Pl. VI, Fig. 33.

Antero-posterior diameter of the bone, 1.5 mm.; lateral, 2 mm. Antero-posterior diameter of the medullary canal, 1 mm.; lateral 2 mm.

The medullary canal contains a very thin layer of marrow around the walls of the bone. There are no trabeculæ. The bone is soft. No cancellous bone.

Structure. There are no distinct external and internal circumferential lamellae. The anterior walls are thicker than the posterior. The bone consists of twenty to twenty-eight concentric lamellae. Their lacunae are narrow and oval and their canaliculi are long, branching or bushy. The lamellae are fairly well developed. In the outer anterior wall they are interrupted by irregularly-shaped whorls of oval and round lacunae, with short, bushy canaliculi. In one or two of them a central canal appears. The whorls are evidently the early stages of Haversian systems. Besides these not a single Haversian system can be found. Large canals cross the bone on their way from the medullary canal to the external surface. They are not numerous. The type of bone is the lamellar.

The peculiar feature is the complete absence of Haversian systems in a mammalian femur.

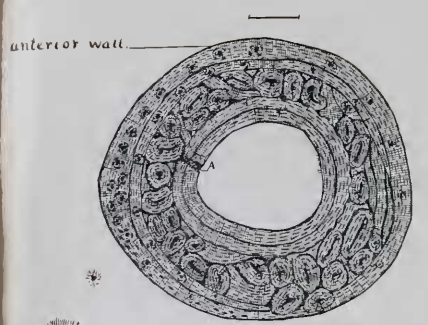


Fig. 27

Femur of woodchuck or ground hog showing two well developed external and internal laminae and irregular Haversian Systems.

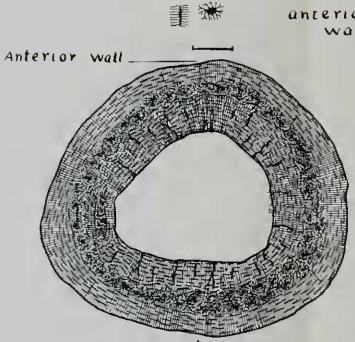


Fig. 28

Femur of a prairie Dog showing wide external, internal circumferential lamellae and narrow ring of Haversian systems.

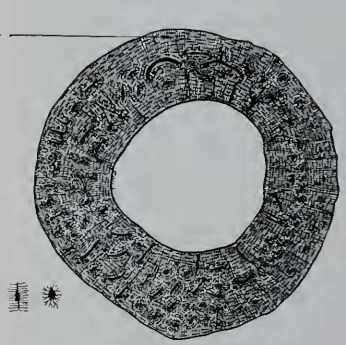


Fig. 29

Femur of a Skunk showing lamellar Character of the bone.

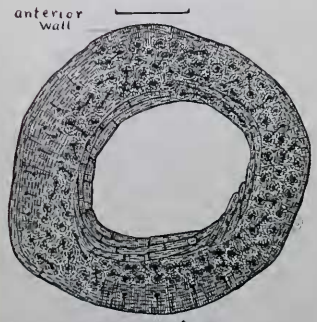


Fig. 30

Femur of a raccoon showing wide lamellae, irregular arrangement of Haversian Systems and internal laminae.

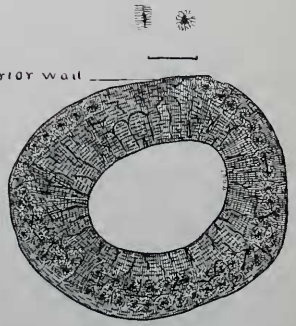


Fig. 31

Femur of a mink showing wide lamellae, Crescent of Haversian Systems and numerous canals.

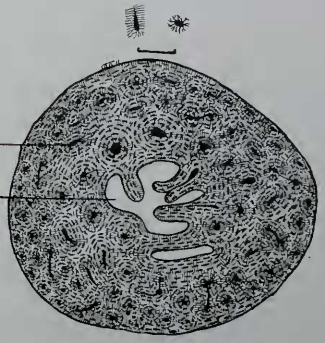


Fig. 32

Cross section of the os penis of the raccoon.

Femur of the Wild Cat.
Pl. VI, Fig. 34.

Antero-posterior diameter of the bone, 13.5 mm.; lateral, 11 mm.

Antero-posterior diameter of the medullary canal, 8 mm.; lateral, 5.5 mm.

The medullary canal is full. No trabeculæ and no cancellous bone are present. The bone is hard.

Structure. 1. Around the outside of the bone is a wide ring of lamellae, interrupted very frequently by incomplete Haversian systems. The ring forms two-thirds of the thickness of the walls of the bone, excepting in the posterior wall, where the central Haversian systems occupy the whole width from the internal circumferential lamellae outward to the circumference. As this ring approaches the posterior wall on the inner side the lamellae separate into laminae. Many canals traverse the ring. For the most part, all of the structural units are indistinct. Around the anterior and a portion of the inner wall is a narrow rim of lamellae, 4-6 in number. The lacunae of the wide lamellar ring are long or oval and their canaliculi are long and branching or bushy. In some places there is a network of lacunae and their canaliculi, a formation which belongs to the lower orders of development.

2. In the anterior wall there is a short crescent of well-developed Haversian systems adjacent to the internal circumferential lamellae. In other portions there is an irregular arrangement of Haversian systems and laminae, complete and incomplete. In the posterior wall a narrow ring of well-developed Haversian systems appear, which is gradually lost in the wide lamellar ring.

3. Around the medullary canal is a well-defined ring of internal circumferential lamellae, varying in thickness from three or four in the posterior wall to thirty in the anterior wall. Numerous large canals cross the ring to communicate with canals within the center of the bone. The lacunae are long and canaliculi long and branched. The bone is of the lamellar type, principally.

Femur of the Cat.

Pl. VI, Fig. 35.

Antero-posterior diameter of the bone, 7.5 mm.; lateral, 9.5 mm. Antero-posterior diameter of medullary canal, 4 mm.; lateral, 5.5 mm.

Medullary canal is full. No trabeculæ. No cancellous bone. The bone is of medium hardness.

Structure. 1. External circumferential lamellae, twenty-three to forty-five in number, form about one-half of the thickness of the wall of the bone. They are inclined to interlace. Near the mid line of the anterior wall four Haversian systems appear in the middle of the lamellar ring. They are well developed and without apparent signification. A short distance from the mid line in the inner wall the lamellar ring divides into a wide outer and narrow inner parts which enclose a crescent-shaped area of Haversian systems. Along the posterior wall a few scattering, incomplete Haversian systems are introduced into the lamellar ring. About the middle of the inner wall is quite a sharp lateral ridge formed by lamellae. The lamellar ring is widest at this point and narrowest in the outer wall. The lamellae, for the most part, are clearly developed and show no signs of a laminar formation, excepting in the anterior wall, where there is a slight tendency toward such an arrangement. The lacunae are long and narrow and the canaliculi are thickly set, long and branching.

2. A ring of well-developed, large and small Haversian systems, widest in the inner wall and narrowest in the outer wall. The ring has irregular boundaries. The systems are generally strongly developed, and are round, elliptical or irregular in cross section. Their lamellae are clearly marked, their lacunae are long and narrow, their canaliculi branching and their Haversian canals are frequently united. Inter-Haversian lamellae, short and irregular, hold the systems together.

3. The internal circumferential lamellae are in the form of two or three laminae in some places and five or six in others. Each lamina is composed of four to six lamellae. Their lacunae are long or oval and their canaliculi are bushy. The laminae do not

present parallel sides, but are wide or narrow, and hence the width of their internal ring varies. Numerous canals pass through the laminae on their way from the medullary canal. The bone is of the lamellar type. The peculiar feature of this bone is the extremely thick ring of lamellae.

Femur of a Small Grey Fox.

Pl. VI, Fig. 36.

Antero-posterior diameter of the bone, 8 mm.; lateral, 9 mm.

Antero-posterior diameter of medullary canal, 5 mm.; lateral, 6.5 mm.

The medullary canal is full. No trabeculæ and no cancellous bone present. The bone is soft.

Structure. 1. A ring of external circumferential lamellae, twenty to thirty in number, surround the bone. In the outer wall the lamellar ring is distinct, but in the inner wall it widens and merges into laminae, which occupy the whole thickness of the wall. The laminae are short and are separated and crossed by intercommunicating canals. On the inner side of the posterior wall is a ridge and the laminae from the inner wall reach the surface at this point and appear to interdigitate with inward extensions from the periosteum. The lacunae are long and narrow, the canaliculi are long and branching.

2. A crescent of well-developed Haversian systems, the horns of which begin a short distance apart in the inner wall, while the widest part of the body occupies the outer wall. The systems are small and large, regular and irregular in shape. Their lamellae are well defined, their lacunae are long and narrow and their canaliculi are branching. Their Haversian canals frequently communicate.

3. Around the medullary canal is a border of Haversian systems, flattened, a few laminae and some lamellae.

The bone is of the complete mixed type. Its peculiar features are the arrangements of the lamellae, laminae and Haversian systems.

Femur of the Wolf.
Pl. VI, Fig. 37.

Antero-posterior diameter of the bone, 16.5 mm.; lateral, 7 mm.
Antero-posterior diameter of the medullary canal, 10 mm.; lateral, 7.5 mm.
The medullary canal is full. No trabeculæ and no cancellous bone.

Structure. 1. Around the outside of the bone is a ring of external circumferential lamellae, sixteen to twenty-one in number, separating into four laminae in the inner and outer walls. The laminae are interrupted here and there by Haversian systems. As the ring approaches the posterior middle line it narrows to three or four lamellae, which gradually merge into the Haversian systems of that region. Shortly after leaving the anterior mid-line of the section, in the inner and outer walls, the external ring is re-enforced by other lamellae, beginning higher in the inner wall than in the outer and increasing in thickness. On each side, from two or three lamellae to five or six laminae interrupted by Haversian systems and forming with the external ring, three-fourths of the whole thickness of the walls of the bone. As the laminae approach the posterior wall they change to Haversian systems, which occupy the whole thickness of the wall, with the exception of a narrow ring of internal circumferential lamellae. The lacunae of the laminae and lamellae are long and narrow and their canaliculi are branching. The laminae are composed of four to eight lamellae with long central canals, which are gradually rolled into Haversian systems of an incomplete nature.

2. A crescent of well-developed Haversian systems, thick in the anterior wall, is situated underneath the external lamellar ring. The systems gradually merge into the posterior group of Haversian systems. They are well developed and have two to five distinct, concentric lamellae, with long lacunae and branching canaliculi. Their Haversian canals frequently unite.

3. A ring of internal circumferential lamellae, thinnest in the posterior wall and gradually increasing in thickness until it expands into six laminae in the mid-line of the anterior wall. The lamellar and laminar lacunae are long and narrow and their canaliculi are

branching. Many large canals pass from the medullary canal into the interior of the bone and communicate with the canals of the laminae and Haversian systems.

The bone is of the mixed type. The peculiar features are the external and internal lamellae expanding into laminae and Haversian systems.

Femur of the Dog.

Pl. VI, Fig. 38.

Antero-posterior diameter of the bone is 14 mm.; lateral, 13 mm. Antero-posterior diameter of the medullary canal, 9 mm.; lateral, 7 mm.

The bone is nearly round; medullary canal is full; no trabeculæ and no cancellous bone. It is of medium hardness. This femur shows different arrangements of lamellæ, laminæ and Haversian systems in different parts of the section.

For descriptive purposes, it will be better to divide the section into imaginary fourths, beginning with the posterior mid line and proceeding around the section to the left or inner wall of the femur.

Structure. First fourth of inner wall.—This portion is composed of the following alternating structures:

1. External circumferential lamellæ, narrow ring.
2. Irregular Haversian systems.
3. Lamellæ (narrow) or lamina.
4. Haversian systems.
5. Lamellæ or lamina.
6. Haversian systems.
7. Internal circumferential lamellæ.

Second fourth of inner wall:

1. External cimcumferential laminæ forming one half of the entire thickness of the wall.
2. Haversian systems, regular in shape, wide.
3. Internal circumferential lamellæ.

Third and fourth fourths of outer wall. These two fourths have the same structure:

1. External circumferential lamellæ.
2. A very wide semicircular band of well-developed Haversian systems.
3. Internal circumferential lamellæ.

The lamellae, laminae and systems are well developed. The lacunae are long and narrow or oval, their canaliculi are long and branching or short and bushy. The Haversian canals communicate freely and wide, prominent canals pass from medullary canal to canals between the laminae. The bone is of the complete mixed type. The peculiar feature of this femur is the decidedly complex arrangement of tis structural units. The outer wall is not at all like the inner wall. The posterior fourth of the inner wall is not like the anterior fourth of the same wall. From a study of structural positions in other femurs, it appears that the particular situation of any structure depends upon its muscular attachments or stress. Wherever muscular stress is greatest, there the Haversian systems are best developed and most numerous, and the laminae are either absent or incomplete. Wherever muscular stress is least, there laminae or lamellae are well developed and the Haversian systems are absent. or few and incompletely formed. Viewed from this viewpoint, the femur of the dog must be subject to various stresses not apparent in many other quadrupeds. If the structure does not depend upon the requirements present, there is no apparent reason for this complex arrangement.

Femur of the Elk.

Pl. VII, Fig. 39.

Antero-posterior diameter of the bone, 35 mm.; lateral, 33 mm.

Antero-posterior diameter of the medullary canal, 23 mm.; lateral, 20 mm.

The medullary canal is full. There are no trabeculæ and no cancellous bone. The bone is brittle and of medium hardness.

Structure. A wide ring of external circumferential lamellae. 14-40 in number, surround the bone. The lamellae are distinct, their lacunae are long and narrow and their canaliculi are long and branching. The ring is widest in the anterior inner, lateral wall, where it is divided into two portions by a canal and by different arrangements of the lamellae. The central ring, constituting the greater part of the bone, consists of fully-developed laminae separated by concentric canals and interrupted at short intervals by completely developed Haversian systems. The laminae are frequently transected

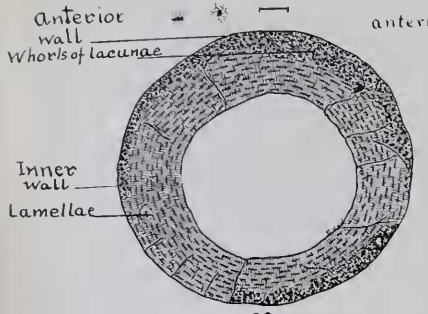


Fig. 33

Femur of a weasel, showing almost pure lamellar type.

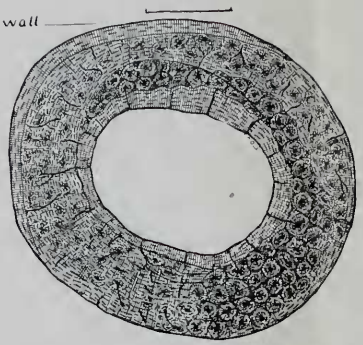


Fig. 34

Femur of a wild cat showing the peculiar arrangement of the structural units.

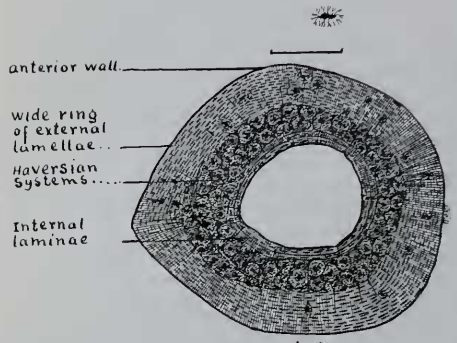


Fig. 35

Femur of a cat showing wide ring of lamellae, irregular ring of Haversian systems and internal laminae

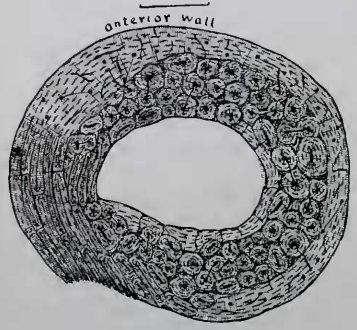


Fig. 36

Femur of a small grey fox showing the peculiar arrangement of lamellae, laminae and Haversian systems

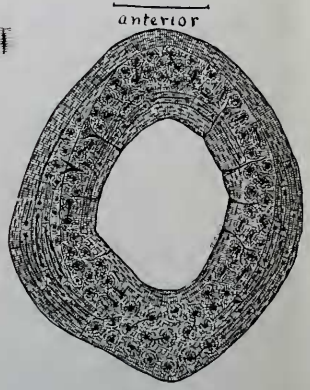


Fig 37

Femur of the wolf showing lamellae, Haversian systems and laminae well developed.

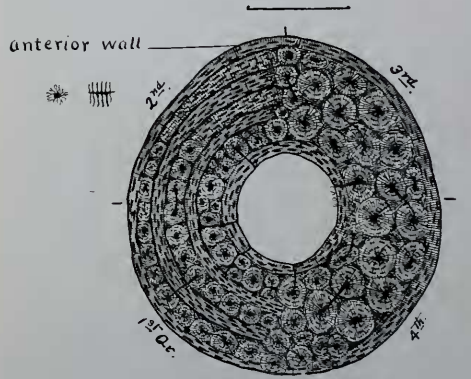


Fig. 38

Femur of a dog showing alternating laminae and Haversian of the inner wall and wide band of Haversian systems of outer wall

by the canals, which freely communicate with each other. They are composed of 5-10-12 lamellae, with long, narrow lacunae and branching canaliculi. They have the appearance of a strong development. The canals are wide and in some places have widened into Haversian systems.

The Haversian systems have 3-9 lamellae, long, narrow lacunae and long branching canaliculi. The Haversian canals are large, round or oval in shape, and freely communicate with each other. There are no incomplete systems in the bone; in fact, there are no incomplete bone structures of any kind. There are more Haversian systems in the outer wall than elsewhere. Beginning at the mid-line of the posterior wall and extending around the outer wall nearly to the anterior mid-line, and occupying a position next to the internal circumferential lamellae, a zone of Haversian systems, three or four in thickness, surround the medullary canal. Their lacunae and canaliculi are completely formed.

In the anterior wall and near the medullary canal are five or six large vascular canals, surrounded by 3-4 lamellae. The bone is of a mixed type, completely developed, with the laminar type predominating.

The peculiar features are the complete development of all the bone structures and their arrangemnt. Th bone is more advanced than that of the deer.

Femur of a Deer (white tailed).

Pl. VII, Fig. 40.

Antero-posterior diameter of the bone, 25 mm.; lateral, 24 mm.
Antero-posterior diameter of the medullary canal, 17 mm.; lateral, 16.5 mm.

The medullary canal is full. No trabeculæ and no cancellous bone are present. The bone is hard.

Structure. The bone consists almost entirely of laminae, which vary in number in the different walls. The anterior-inner-lateral wall is thickest and shows 31-33 laminae, the anterior-middle wall has 26-27, the outer-mid-lateral wall has 17-18 and the posterior lateral walls 16-17. The laminae are well developed, separated and

crossed by wide canals and are composed of three to six or eight lamellae. Their lacunae are long, narrow and completely developed. The canaliculi are long and branching. Here and there are found a few scattered incomplete Haversian systems produced by a circular widening of the concentric canals and the bending of a few lamellae around the circular opening. The laminae form the entire section, excepting that of the posterior ridge, which is composed of Haversian systems and have a general concentric arrangement. There are no distinct external circumferential lamellae. In the external half of the section the laminae are arranged concentrically around the entire bone, excepting at the posterior ridge. In the internal half of the anterior, inner, and posterior-inner-lateral walls the laminae are arranged in concentric arcs of circles of shorter diameters, beginning and ending in the internal circumferential laminae.

By this arrangement the internal circumferential laminae are very distinctly marked off in this region. In the outer wall the internal laminae disappear and a regular concentric laminar arrangement occupies the whole thickness of the wall. The canals between the laminae cross them at all angles and communicate freely with each other.

The internal circumferential laminae form an irregularly-shaped boundary of the medullary canal only on the anterior-inner-lateral and posterior walls. They are two or three in number and are frequently crossed by canals extending outward from the medullary canal. The surface of the posterior ridge shows the tendon attachments of muscles. Extending from this surface to the internal circumferential laminae, and for a short distance on either side of the posterior mid-line, is the one area of Haversian systems. They are irregular in shape, well-developed, for the most part, and by their position indicate their importance in the valuation of muscular stress. Their lacunae are long and narrow, generally. A few, however, show round or oval lacunae, with short, bushy canaliculi. These form the weaker spots of the bone.

The peculiar features of this bone are its almost complete laminar structure, its one area of Haversian systems and its association in type with the pig and turkeys. These animals appear to be

Anteri

Vascula

Outer wal

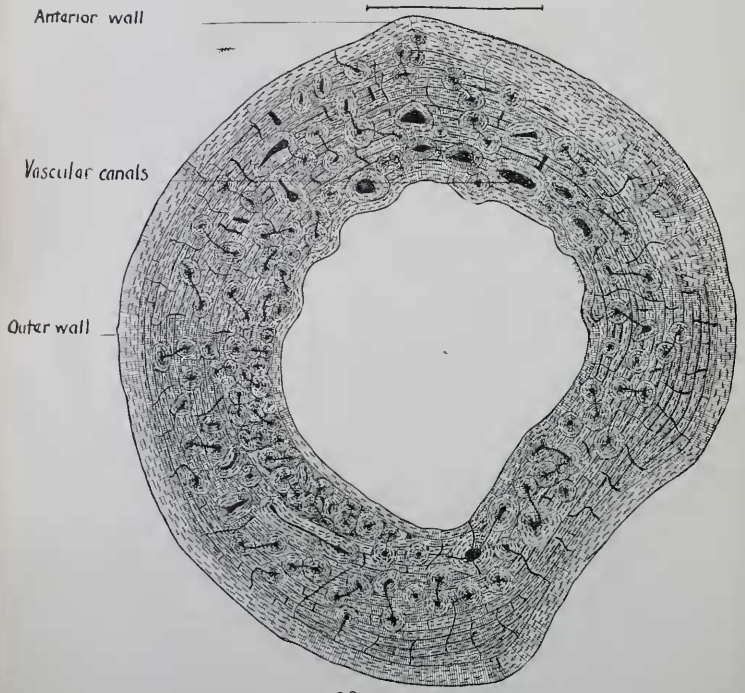


Fig. 39.
Left Femur of an Elk showing fully developed Haversian systems, laminae, lamellae, and lacunae.

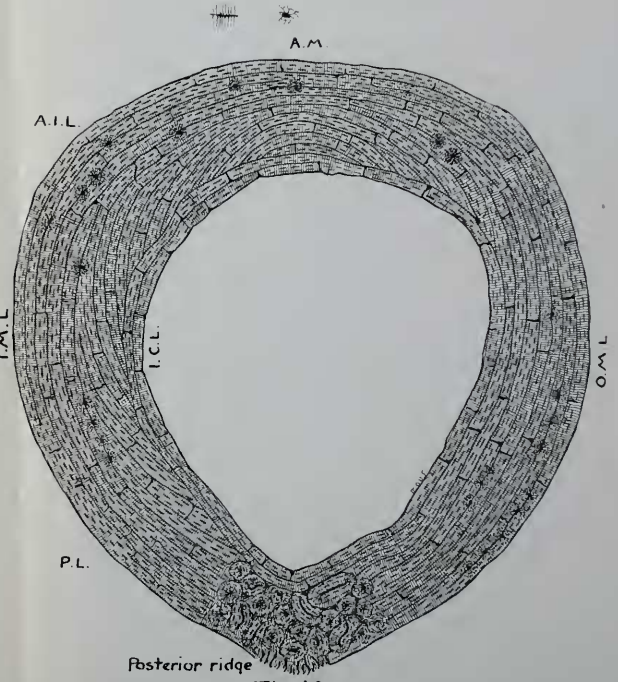


Fig. 40.
Femur of Deer (white tail) showing laminar type of structure, posterior Haversian systems.
A.M. - Anterior Middle. A.I.L. - Anterior inner lateral.
O.L.M. - outer mid-lateral. P.L. posterior lateral.
I.M.L. - inner mid-lateral I.C.L. Internal circumferential laminae.